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GENERAL APPROACHES TO ANIMAL NUTRITION RESEARCH AND ITS RELEVANCE TO FISH PRODUCTION in THE ASIAN REGION

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ABSTRACT

The paper attempts to discuss the general approaches to animal nutrition research and its influence on research in fish nutrition and production in the Asian region. It briefly describes the historical aspects and the establishment of approximately 40 nutrients now required by the animal body. The objectives of animal nutrition research are :

(i) identification and definition of the feed resources,
(ii) assessment of nutritive value,
(iii) utilisation in efficient feeding systems, and
(iv) determination of nutrient requirement.

These objectives are discussed with reference to their relevance to research in fish nutrition, and especially in relation to available feeds (forages, energy and protein concentrates, crop residues, agro-industrial by-products and non-conventional feeds) in Asia and feed efficiency. The importance of feeding standards is stressed, and their determination needs to consider species, age, physiological state of production and extent of muscular activity. A strategy for fish feed formulation and production is discussed involving an initial exploratory phase and a second continuing phase on refinements. These phases provide for improved efficiences in the utilisation of the feed resources and the feeding and nutrition of fish. The emphasis on the latter phase can however, ensure an impact on expanded and maximisation of economic fish production per hectare in the region.

I INTRODUCTION

The principal constraint in animal production systems is feed. The reference to feed includes such important factors as quantitative and qualitative issues, digestion and metabolism in the animal body. These important factors thus need to be considered in the wider context of fluctuating feed supplies, variations in nutritive value and relevanceto feeding systems in the Asian region. Undernutrition and malnutrition prevents the animals from expressing their genetic potential and results in decreased protein production at a time when such protein supplies are in ever increasing demand to keep pace with human population growth. Surplus nutrition is wasteful of precious nutrients, increases the cost of production and is not cost-effective. A balance thus needs to be made to ensure that appropriate nutrient supply can match predictable responses in the animal body which in regard to products (eg. meat, milk or fibre) are economic.

In general, it is especially important in seeking efficiency in feeding systems for a specific situation to maintain an appropriate species, to aim for a realistic potential level of production, to take advantage of the available dietary ingredients and identify the objectives clearly in terms of production and profitability. Concerning fish nutrition, reference is made to the discussion on methodological approaches to research and development by Cho, Cowey and Watanabe (1985).

The intent of this paper is to provide some background about the general approaches and principles of research on farm animals of economic significance to man. It has been suggested that such treatment in the paper will be of potential value in providing an understanding of how research has been initiated, developed and made to ensure maximum productivity from animals.

II Historical aspects

This history of nutrition stemmed from the realisation that nutrition involves chemical reactions and physiological processes. Lavoisier the French chemist was the first to establish the chemical basis of nutrition with his famous respiration experiments before the French revolution. It was recognised in the early nineteeth century that nutrition involved the need for carbohydrates, proteins, and fats and eventually also of macro and micro minerals. The former included mainly calcium and magnesium, and the latter sodium florine, iron, potassium and sulphur. During the last seventy years, the need for yet another nutrient was made by the discovery and isolation of many vitamins, based on work with rats. These developments together have now established that the animal body requires approximately 40 nutrients.

Developments in the nutritive value of feeds and how the various chemical reactions and physiological processes are involved in body function have been possible because of the contributions of the various branches of science notably chemistry, biochemistry and physiology. Attendent to this are the contributions of animals as test subjects for example, in detecting deficiencies of nutrients, imbalances in the diet or the effects of various dietary variables. The laboratory rat for example, has contributed to our knowledge on vitamins, amino-acids and minerals. Likewise, mice, guinea pigs, hamsters and dogs have also been used extensively as laboratory animals. Of the farm animals, goats, cattle, sheep, pigs and chickens have been used variously to evaluate the value of feeds, effect of dietary variables and the potential capacity of dietary ingredients in suitable proportions to sustain the requirements for maintenance, growth and reproduction.

Whereas in the past the tendency has been essentially ad hoc and macro in approach, the science of nutrition today is one of detail, precision and completeness in terms of those requirements of the body that can understand the value and inter-relationships of different nutrients to ensure efficient metabolic function and high performance. This expanding development has been greatly facilitated by physics, electronics and instrumentation. Examples in this connections are the use of spectrographs, radio isotopes, scintillation counters and electron microscopes in the analyses of feed ingredients.

III OBJECTIVES IN ANIMAL NUTRITION RESEARCH

It is essential to define and constantly keep in perspective the objectives of animal nutrition research. These are as follows :

A. Identification and definition of the feed resources
B. Assessment of nutritive value
C. Utilisation in efficient feeding systems, and
D. Determination of nutrient requirements.

It is appropriate to discuss each of these factors briefly.

A. Identification and definition of feed resources

The identification and definition of the feed resources seeks to identify and clearly define the available feed resources within a particularly situation, district, state and the country as a whole. This is essentially a feed inventory of all available feeds produced, which needs to be compiled as completely as is feasible. The inventory should identify and then quantify the feeds products by considering inter alia the following aspects :

1) Quantities and kinds of materials available. This involves the use of statistical data and other sources of information for example, area the crop, average yield per hectare and extraction rates. These ancillary data need to be defined. Where assumptions are used these also need to be stated.
2) Brief physical description (eg. bulky, roughage, slurry, wet or dry).
3) Location of production.
4) Seasonality of production.
5) Present use by animal category.
6) Alternative uses if any (eg. as fertiliser).

7) Potential for processing.
8) Cost of collection, handling, transportation and processing.
9) Impact on prevailing and future utilisation.

For purposes of classification five broad groups of feeds are identified :

(i) Forages (Grasses and legumes).
(ii) Energy and protein concentrates.
(iii) Crop residues.
(iv) Agro-industrial by-products, and
(v) Non-coventional feeds.

The first group includes all types of grasses, shrubs and legumes that are of potential value to animals. Examples are elephant or Napier grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), cassava leaves (*Manihot enculenta* Crantz) and leucaena (*Leucaena leucocephala*).

Energy and protein concentrates include such energy sources as the cereals (maize, wheat and barley), root crops like cassava and sweet potatoes and also fats such as tallow, lard and palm oil. The protein concentrates refer mainly to fish meals, oil seed meals and cakes, for example soyabean meal.

Crop residues and agro-industrial by-products constitute a group which is very important in most countries, and which is probably also underutilised. By virtue of being indigenous and therefore traditionally used, the potential value rests in not only reduced cost of production, but also the possibility that their intensive use can encourage possible expansion of components of the animal industry. In recent years therefore, this group has been the focus of wide and concerted research effort throughout the Asian region. The best example of this is seen in the efforts to increase the utilisation by ruminants, of rice straw after urea or ammonia treatment or by microbial degradation to improve the nutritive value.

Crop residues are produced from crop growth and production are usually fibrous materials. They may or may not be agricultural by-products. Agro-industrial by-products on the other hand, are feed materials that are produced usually from agro-based industries on a commercial basis. Whereas crop residues are mainly utilisable by ruminants (buffaloes, cattle, goats and sheep) usually at the farm level, agro-industrial by-products on the other hand, are less bulky and better utilised by non-ruminants (pigs, poultry and ducks) and also fish. The differences are mainly due to nutritive quality, with crop residues being deficient in energy, nitrogen (protein) and micro-nutrients and agro-industrial by-product generally having higher contents of each of these. Examples of these two categories of feeds and the approximate nutritive values are given in table 1.

(Table 1 here)

The fifth category, non-conventional feed resources include all those categories of feeds that are not traditonally used by animals or even fishes. By definition, non-conventional feed resources (NCFR) refer to all those feeds that have not been tradtionally used in animal feeding and or not normally used in commercially produced rations for livestocks. NCFR include feeds from animal and perennial crop production and also residues and wastes from animal sources and the processing of food for human consumption.

Non-conventional feedstuffs have a number of characteristics that are peculiar to them (Devendra, 1985). These are as follows :

(i) They are the end products of production and consumption that have not been used, recycled or salvaged.

(ii) They are mainly organic and can be in a solid, slurry or liquid form.

TABLE 1

NUTRITIONAL CHARACTERISTICS OF SOME CROP RESIDUES AND AGRO-INDUSTRIAL BY-PRODUCTS IN THE ASIAN REGION

Feed source	Moisture (%)	Crude Protein+ (%)	Crude fibre+ (%)	Organic matter digestibility (%)
Crop residues[1]				
Cassava leaves[2]	73.6-78.8	21.7-26.6	8.1-23.2	55.1-61.0
Gliricidia[2]	80.8	24.6	21.8	50.4
Groundnut vines	71.3	9.2	24.1	60.0-68.0
Leucaena forage[2]	75.3-79.2	20.0-25.0	16.9-25.3	51.1-54.1
Maize stover	12.8-16.3	5.0	28.3	61.0
Pigeon pea forage[2]	71.1-74.8	20.0-25.6	17.6-22.6	47.2-55.4
Rice straw	9.0-9.2	3.3-4.5	28.8-33.6	48.1-56.4
Sesbania[2]	13.4	22.6	18.4	52.8
Sugarcane tops	72.0	3.8	38.0	43.0
Sweet potato vines	99.3	13.3	17.2	60.2
By-products[1]				
Bagasse	3.9-4.7	2.9-6.9	10.3-39.3	49.0
Brewers grains	9.8-10.8	24.0-27.4	15.9-17.1	60.0
Cocoa pod husks	89.6	6.0	31.5	45.0
Coconut cake[3]	10.0	18.0	12.0	78.0
Coffee seed hulls	8.0	6.9	45.6	31.0
Molasses	24.5	1.6	-	108
Palm Kernel Cake[4]	5.7	14.2	20.2	66.8
Palm oil mill effluent	78.0-89.0	9.6	11.5	58.1-64.2
Palm press fibre	13.8	4.0	36.4	30.8
Pineapple waste	6.8	4.9	20.8	76.0
Poultry litter	6.4	40.4-45.7	18.0-21.2	54.2
Rice bran	9.3-11.4	11.4-17.4	10.4-20.0	62.0
Rice hulls	6.7-9.7	1.5-2.8	14.3-41.4	37.0
Wheat middlings	12.7	20.5	9.0	69.0-71.4

[1] These include non-conventional feeds

[2] These are not really crop residues

[3] Expeller pressed

[4] Solvent extracted

+ On dry matter basis

(iii) Their economic value is often less than the cost of their collection and transformation for use, and consequently they are discharged as wastes.

(iv) The feed crops which generate valuable NCFR are excellent sources of fermentable carbohydrates eg. cassava and sweet potato and this is an advantage to ruminants because of their ability to utilise inorganic nitrogen.

(v) Fruit wastes such as banana rejects and pineapple pulp by comparison have sugars which are energetically very beneficial.

(vi) Concerning the feeds of crop origin, the majority are bulky poor-quality cellulosic roughages with a high crude fibre and low nitrogen contents, suitable for feeding to ruminants.

(vii) Some of the feeds have deleterious efforts on animals, and not enough is known about the nature of the active principles and ways of alleviating the effects.

(viii) They have considerable potential as feed materials, and for some, their value can be increased if there were economically justifiable technological means for converting them into some usable products.

(ix) More information is required on chemical composition, nutritive value, toxic factors and value in feeding systems.

It has been estimated that in Asia and the Pacific, NCFR account for approximately 194.1 x 10^6 tonnes which is about 45 per cent of the total availability from field and plantation crops. Approximately 80 per cent of the NCFR is field crops and 93 per cent of the feeds in tree crop cultivation (table 2) are principally suited for feeding ruminants.

(Table 2 here)

TABLE 2

THE AVAILABILITY OF NON-CONVENTIONAL FEED RESOURCES IN ASIA AND THE PACIFIC (Devendra, 1985)

Category	Availability (10^6 tonne)
Field Crops	189.9
Tree Crops	4.2
Total	194.1+

+ Represents 44.9% of the total availability from field and plantation crops

Crop residues, agro-industrial by-products and NCFR are essentially of three categories :

(a) Energy rich feeds (eg bananas, citrus fruits and pineapple wastes).

(b) Protein supplements such as oilseed cakes and meals, by-products of animal processing (eg. feather meal and poultry litter), low quality pulses and fishmeals.

(c) By-products from cereal milling and milk processing.

B. Assessment of nutritive value

The assessment of nutritive value aims at establishing a clear understanding of the nutrients available in the feed, the extent of this availability in metabolic terms and the attractiveness of the feed for animals. The following procedures are important:

(i) Proximate analyses (to include minerals)

(ii) In vitro digestibility

(iii) In vivo digestibility

(iv) Toxic components

(v) Amino acid profiles

The assessment of digestibility enables the determination of digestible energy (DE) and metabolisable energy (ME). It is also possible to calculate the nutritive value of the feed based on the proximate analyses data. The following expressions of energy value are in use :

(i) Starch equivalent (SE) - United Kingdom

(ii) The Scandinavian Fodder Unit (SFU) - Denmark

(iii) Fattening Fodder Units (FFU) - Denmark

(iv) The French system of Fodder Equivalents - France

(v) Rostock NEF system - Germany

(vi) Net energy of lactation system - Netherlands

(vii) California system - U.S.A.
(viii) Total digestible nutrients (TDN) - U.S.A.
(ix) Metabolisable energy (ME) - United Kingdom
(x) Digestible energy (DE) - United Kingdom

At present the feeding systems based on ME and DE are used mostly for non-ruminant animals and also for fish, whereas the net energy systems (eg SE, SFU or FFU) are more applied reserved for fattening. Of these systems, the ME system is possibly the most widely used presently.

With respect to proteins, the following indices are used to describe quality :

(i) Digestible crude protein (DCP)
(ii) True protein (TP)
(iii) Protein efficiency ratio (PER)
(iv) Gross protein value (GPV)
(v) Protein replacement value (PRV)
(vi) Biological value (BV)
(vii) Biological assays
(viii) Protein equivalent (PE)
(ix) Degradability

Of these indices, DCP and BV are used very widely. Recently, increasing use is also being made of degradability in the rumen.

Feeds should be evaluated with animals and so with fishes (species and physiological state) to which the information will be ultimately applied. This implies that the extrapolation of data across species may be inaccurate and therefore not desirable.

C. Utilisation in efficient feeding sytems

Once a feed has been identified and there is adequate information on nutritive value, the next step is an assessment of its value in feeding systems. The following aspects are considered essential for this assessment.

- (i) Voluntary intake (specifying animal species and level of feeding).
- (ii) Digestibility coefficients (specifying animal species, level of feeding, supplementation and any processing.)
- (iii) Feeding trials which specify the proportion of the feed incorporated.
- (iv) Any observed side effects.

Animal performance is usually measured by such parameters as feed intake, growth rate and milk production. Growth rate, biomass production and reproductive capability apply to fish.

D. Nutrient requirements

The nutrient requirements refer to the defined needs of the body in terms of energy, protein, minerals and vitamins to enable it to survive and produce. The extent to which animals and fish can maximise production is directly related to the level and quality of dietary nutrients supplied above the maintenance requirements.

Feeding trials need to be undertaken which are well controlled and carefully monitored especially in regard to the use of feed ingredients and diets over time. In particular, the following issues will need to be carefully defined as the results are specific a particular situation :

- (i) Species of animal or fish
- (ii) Age of animal or fish
- (iii) Physiological state of production (maintenance, growth reproduction).
- (iv) Extent of muscular activity (confined or grazing).

It is possible to undertake the utilisation and effectiveness of feeds in efficient feeding systems as in (C) with the determination of nutrient requirements. Digestibility coefficients are also determined in relation to voluntary intake, feeding level and type of treatment.

Based on this approach, there exists today several nutrient requirement standards that are widely used throughout the world. These include for example, the A.R.C. Nutrient Requirements of Farm Animals, 1. Poultry (1963), and 3. Pigs (1967), A.R.C. Nutrient Requirements for Livestock (1980) and N.R.C. Nutrient Requirements for Goats (1983). Kearl (1982) has published nutrient requirements for ruminants in the developing countries based on a reveiw of the literature. In recent years, there have been concerted attempts in several countries to develop their own feeding standards especially for ruminants. Similarly there also exists the N.R.C. (1983) requirements for warm water fishes and shellfishes.

IV Importance of feeding standards

Very recently, the question has been asked (Jackson, 1981), "who needs feeding standards" and the same author replied "no-one really needs them". Jackson's conclusion is based on the fact that the feeding standards dictate high levels of grain use, which is not the case in the developing countries, and that the existing feeding standards are inadequate for application to small farm systems that are characteristic of Asia (Devendra, 1983). Such a view is also endorsed by some, for example, Preston, (1985) who advocates that production should simply be matched to available resources, including feed resources for maximising animal performance based on an understanding of rumen fermentation, digestion and metabolism in the animal.

Jackson's view has been refuted and challenged by Minson (1982) who argues that feeding standards "form the basis of our quantitative understanding of animal production whether under grazing or stall feeding conditions".

It is relevant to keep in mind that the objective of feeding standards is to provide to animals amounts of nutrients that are essential for maintenance and a stated level of production. This approach ensures that the objectives of production and profitability are met by the application of feeding standards. This situation is also true for fish (Halver, 1979) and for example, the rainbow trout (Lall and Bishop, 1979).

The focus of feeding trials experiments should not exclusively be directed towards determining nutrient requirements. Rather, it should be directed towards predictable responses to a diet or to incremental amounts of added dietary nutrients within which it will be feasible to determine the nutrient requirements.

V STRATEGY FOR FISH FEED FORMULATION AND PRODUCTION

In practice, diet formulation and development usually follows the pathway of using traditional feed ingredients to determine performance and also nutrient requirements. This phase can be termed exploratory whereby traditional feed ingredients, based on a knowledge of nutritive value are formulated for use. Based on the effective utilisation of the formulated diets, it is feasible to determine the nutrient requirements.

The second continuing phase can be termed one of refinements which will consider additionally important issues such as the use of NCFR, nutrient variables (energy, protein, minerals and vitamins), supplementation, import substitution and economic considerations. Very rarely is the second phase included into the phase one effort mainly because of inadequate confidence, extent of the nutrient needs and the level of performance.

The two steps in sequence thus provide for a more assured pathway of identifying nutrient requirements with production, and therefore the development of an orderly strategy for the development of fish feed formulations. Such a strategy has the final objective of ensuring maximum and economic production per hectare. This includes integrated crop-animal systems and specifically also to the future potential of aquaculture. Figure 1 presents a schematic representation of the strategy.

(Figure 1 here)

A review of the types of feed ingredients now being used for fish nutrition studies in various laboratories enables two general conclusions to be drawn :

(i) With very few exceptions, the feeds that are currently being used are identical to those used by animals. This means that there is really no need for placing much more emphasis on proximate analyses. However, it is essential to ensure continuing work on the inherent availability of the nutrients to fishes, especially of amino acids and minerals.

(ii) Rapid progress in fish nutrition work can be achieved by placing more emphasis in the Phase II efforts in Figure 1 of examining refinements which can stimulate and make an impact on production.

VI Issues of practical diet formulation

These are a number of practical diet formulations that are obviously essential in fish nutrition. It is not intended for reasons of brevity to discuss these in detail, since in any case, some aspects of this has been previously considered (Halver, 1976; Lovell, 1979; Hastings, 1979). It is proposed to consider only two aspects that are relevant :

(i) use of indigenous feed, and
(ii) economic considerations.

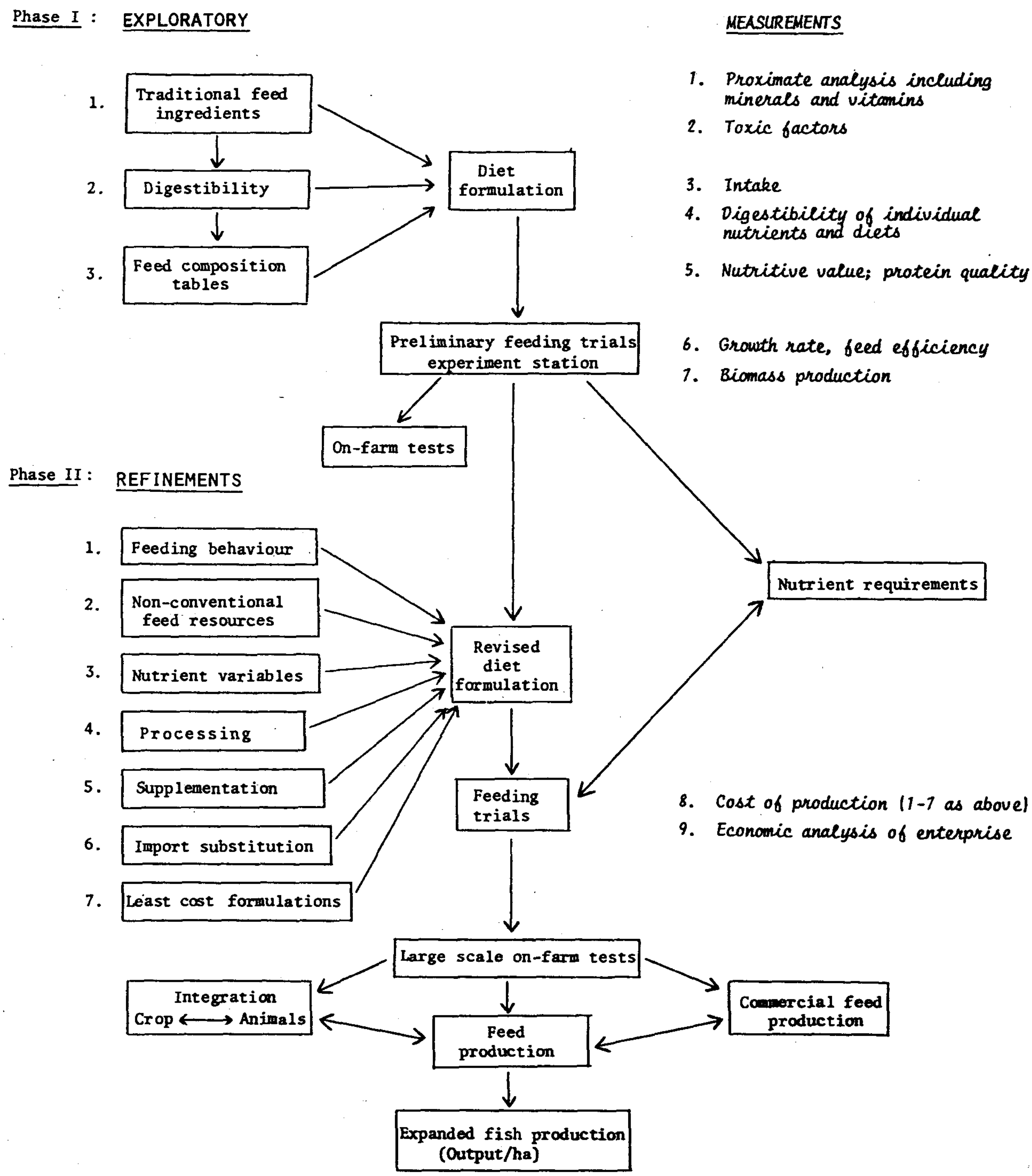

FIGURE 1. A STRATEGY FOR FISH FEED FORMULATION AND PRODUCTION

(i) Use of indigenous feeds

The utilisation of indigenous feed ingredients assumes that there exist substitutes for the traditional energy (eg. maize) and protein sources (eg. fish meal) that are normally consumed by fish. This is clearly an area that fish nutritionists can borrow heavily from the advances that have been in the same context with the nutrition of pigs, poultry and ducks. Table 3 lists the more important energy and protein feed ingredients that are found in Asia and which have potential for use in fish nutrition.

(Table 3 here)

In this context it is encouraging to note that attempts are already underway to explore for example, the value of such feeds as carpet grass (Axonopus compresses) and napier grass (P.purpureum) by the grass carp (Ctenopharyngodon idella), and yam leaves (Colocasium antiquorum) by kalui (Osphoomenus gouramy) and processed fish meal in Singapore (Chou, 1985). The latter for example showed that use of processed Singapore fish meal gave a better performance in young see bass (Lates calcarifer Bloch) than the meal from elsewhere. Broken rice has been used in Thailand (Chuapoehuk and Pothisoong, 1985) and rice bran in Indonesia (Suhenda and Djajadiredja, 1985), Malaysia (Pathmasothy, 1895) and Sri Lanka (Wannigama, Weerakoon and Muthukumarana, 1985).

(ii) Economic considerations

Since as in the case with non-ruminants, the level of protein is the most expensive component of the diet, it is logical to explore all possible ways to decrease this cost, and hence the cost of production and the margin of profits. Thus, successful results in this context have been reported by Gropp et al.(1979)

TABLE 3

SOME IMPORTANT ENERGY AND PROTEIN FEEDS IN ASIA

Energy feeds		Protein feeds
Bananas	waste+	Blood meal
Cassava	- chips	Cassava leaves+
	- waste	Castor seed cake+
Maize	- bran	Coconut cake
	- germ meal	Cottonseed cake
Millet	- broken grains	Feather meal (Hydrolysed)
Rice	- broken grains	Fish meal
Sago	- waste	Gliricidia leaves+
Sugarcane	- molasses	Groundnut cake
Sweet potatoes		Leucaena (ipil-ipil) leaves+
Wheat	- broken grains	Meat meal
	- bran	Palm kernel cake
	- middlings	Pigeon pea leaves+
		Rice bran
		Sal seed cake+
		Soyabean meal

+ These are non-conventional feeds.

on the partial or complete substitution of 70 per cent fish meal by a mixture of poultry by-product meal and hydrolysed feathery meal in the rainbow trout (Salmo gairdneri). Likewise also, poultry by-products and alkali yeast gave equally good results. Table 4 summarises these results. Similarly, squid meal has been used successfully to replace rice bran for shrimp growth.

(Table 4 here)

Apart from the immediate benefit of reducing the cost of production and increasing profitability, successful import substitution tends to reduce the drain on foreign exchange, especially as it concerns those feeds that are imported at high cost. Also, by dependence on fishmeal as the major feed ingredient is constrained by dwindling supplies in the world market, rising costs and competition with the demand for feeding pigs, poultry and lactating ruminants.

VII FEED EFFICIENCY

It may be of interest to refer and make brief comparisions between the efficencies of converting animal feeds into human foods. Table 5 shows the percentage of gross energy and protein in the feed of domestic animals as food producers.

The position with fish does not appear to be well documented, but Brett (1971) has reported gross efficiencies from 10 to 40 per cent. The higher values for energy in fish suggest an efficiency which is clearly superior in comparison to the energetic efficiency of most domestic animals. A similar position exists with protein. The limited results emphasise that the fish uses energy and protein in the feed very efficiently.

(Table 5 here)

TABLE 4

WEIGHT GAIN AND FEED EFFICIENCY OF RAINBOW TROUT FOR EXPERIMENT E XII/75 (104 EXPERIMENTAL DAYS, 17.4° MEAN WATER TEMPERATURE) TO TEST DIETARY REPLACEMENT OF FISH MEAL BY ALKANE YEAST (Gropp *et al*., 1979)

	Percent replacement of fish meal protein			
Poultry by-products	50	50	50	50
Alkane yeast	-	25	50	50 + AA[+]
Gain (g)	210	218	216	221
(relative figures)	(100)	(104)	(103)	(105)
Feed efficiency	1.38	1.34	1.36	1.32
(relative figures)	(100)	(97)	(98)	(95)

[+] Amino acids

TABLE 5

EFFICIENCY OF CONVERTING ANIMAL FEEDS INTO HUMAN FOODS (Maynard *et al*., 1979)

Animal product	Percentage recovered	
	Energy	Protein
Cattle (milk)	15-20	15-36
Poultry (eggs)	10-18	10-30
Pigs (pork)	14-20	14-20
Poultry (broilers)	6-11	17-23
Cattle (beef)	3-8	4-15
Fish*	10-40	40+

*Brett (1971)

+Hastings (1979)

VIII CONCLUSIONS

Improved efficiencies in diet development and nutrition by the fisheries sector are essential for further progress in fish production. Traditional concepts of fish nutriton developed in classical studies essentially in western environments are important and essential. However, these must also serve as guidelines for pragmatic application in real farm situations in Asia where both the fish genetic and available feed resources are quite different. In particular, there is need for modifications and refinements to traditonal diet formulations to take advantage of indigenous feed ingredients and appropriate feeding systems that can ensure high performance and profitability. This approach needs to be coupled to objective innovations to maximise production. This is because the long run perspective of fisheries supply and demand is for increases in real fish prices which are expected to be associated with reduced consumption below the potential demand and difficulties in the management of important fisheries (F.A.O., 1981).

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